DRAFT

National Aeronautics and Space Administration

UNIVERSE STRATEGIC ROADMAP COMMITTEE

March 15-16, 2005
Greenbelt Marriott Hotel
Greenbelt, Maryland

MEETING REPORT
[DRAFT]

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Kathryn Flanagan, co-chair	Anne Kinney, co-chair
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Nicholas White, co-chair	Michael Salamon, Designated Federal Official

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Draft minutes: March 21, 2005
Mark Bernstein, consultant
Infonetic

Session of Tuesday, March 15:

INTRODUCTION

Michael Salamon called the meeting to order. Those present were informed that this was a FACA [Federal Advisory Committee Act] meeting and that, as such, only committee members were permitted to speak unless recognized by the chair. He added that time would be available during the working lunch for public comments. White then reviewed the agenda, noting that co-chair Anne Kinney would have to leave early. Panel members introduced themselves. Anne Kinney noted the presence of Tricia Pengra and Richard Capps of the NASA APIO [Advanced Planning and Integration Office], who might be able to assist with queries members might have on SR integration activities.

Anne Kinney then spoke briefly, introducing the topic of competed line of missions. There has been, she said, discussion that Universe Division is the only division that does not have a competed line. The group might want to consider this in its deliberations. If Universe Division did, would all/some of the division's science be included in this line? Would all the science be subject to competition, or would it be that this year the competition would be for, say, Black Hole Finder? She suggested this could be done with a budget of $260 million annually. She noted the tendency to 'push each project to the limit,' so that in the end sophisticated risk analysis was required to ensure it had not been pushed too far. Steve Kahn asked what the difference would be between this and Explorer Class missions. Kinney replied that this might be Explorer Class as the division might want to do it. She posed the questions: how would a competed line mesh with our desired strategic missions? How would this scientific group prioritize these missions and what science would you attempt to do? She urged attention to smaller more frequent missions, saying that one of the problems for Universe Division was that everything it did was a huge strategic mission.

Michael Salamon, Designated Federal Official [DFO], gave a status report on the roadmap process. He called attention to two deadlines. The initial report is due April 15; the committee will not complete that at this session, but off-line during a later telecon. June 1 is the deadline for the complete report to go to NRC for review and commentary. The integration teams will use materials from all 28 strategic and capabilities roadmap groups; strategic roadmap information will be available to capabilities roadmaps before the latter's final reports are due. Other groups will have access to this committee interim report, and vice versa. The April 15 draft is to be 20 pages of informal narrative. The interim report will include budget assumptions; input on that is needed now.

The interim report is to include roadmap achievements; roadmap requirements and roadmap summary. Anne Kinney asked whether 'achievement' meant a scientific result. Michael Salamon said that it did; e.g., something learned about Dark Energy. Stephen Kahn observed that if the timescale was used, the integration work might alter the timeline; would the group then revisit it? Salamon said there was some circularity to it: the timeline was rooted in the idea that there will be a budget constraint, which by itself will push certain programs ahead in time. The general guideline was that the budget level would remain the same over time. Anne Kinney noted that one very relevant piece of information was the launch date for Con-X, Lisa and the Einstein probes under the current budget. Salamon noted that budget work would need to be completed after the meeting.

Nicholas White said time for discussion existed on Wednesday afternoon. He noted that the group needed to identify milestones and missions that tie this group to any other group. The substance of the June 1 roadmap, he said, was a subject for a later meeting. Kathryn Flanagan noted that the dates used for the initial roadmap were given as preferred, suggesting some flexibility. Salamon agreed. Brief discussion ensued on possible conflicts of interest; committee members would be filling out a list of associations.

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VISION MISSION PRESENTATIONS:

Big Bang Observer – Sterl Phinney
Sterl Phinney presented the status report on Big Bang Observer [BBO], whose design goal is the direct detection of gravitational waves due to quantum fluctuations in the pre-inflation universe. He described the conditions needed to achieve this and the physics underlying the project. He presented a possible BBO configuration and launch configuration and outlined the technology needs. He said that were serious lifetime issues for the lasers BBO would require.

Black Hole Imager [MAXIM] -- Keith Gendreau
BHI, Keith Gendreau said, is dedicated to high resolution x-ray imaging of black holes. It will map the motions of matter in the vicinity of a black hole; map the release of energy from black hole disks; undertake the direct imaging of strong field general relativistic effects, and determine how relativistic jets are formed. The project, he added, combines science with exploration; it will provide a six order of magnitude jump in angular resolution which will, he said, reveal things both unknown and unexpected. He noted there as great public curiosity about black holes and BHI would satisfy that curiosity. Sterl Phinney asked how accurate the formation flying needed to be. Jakob van Zyl asked what would be the typical length of an observation. Gendreau replied 100 kilo-seconds. He added that formation flying remained a hurdle, but did not expect much difficulty with the metrology.

Generation-X -- Dan Schwartz
Dan Schwartz reported that the key science objective of Generation-X is to understand the development of structure and the cycles of matter and energy in the evolving universe. Two mission concepts – formation flying and constellation flying – are under consideration. The adjustable bi-morph [??] mirror that will be utilized is a technology driver. He said the key science was to observe first black holes, stars and galaxies. Gen-X will trace the evolution of black holes, galaxies, clusters and filaments and undertake physics in extreme environments. It will have an effective area of 100 square meters, with fine angular resolution: 0.1." Gen-X will require innovative active approaches to mirror figure control. Asked why high angular resolution was to be used, Schwartz said it would provide a more detailed picture. He noted that this project had elicited the participation of 75 international scientists from 14 institutions with five industry partners. In response to a question, Schwartz said the detector was a silicon type. He added that there were technology challenges but no 'show stoppers.' One key feature, he said, would be the adjusting of the mirrors in orbit, on the expectation that launch would knock them out of configuration.

Large UV/Optical Telescope [LUVO] -- Jim Green
Jim Green outlined basic questions in physics [the nature of the universe; the boundaries of physics; is there life out there?] and gave his view on which of these were addressed by current missions. LUVO, he said, would address an important range of questions, including how metals are created and distributed; how modern galaxies are assembled; how stars and planetary systems form; and where are the baryons in the modern universe, and how are they distributed. Without LUVO, he said, no strategic mission would be performing large scale structure and chemical evolution; he added that HST quality imaging, a high point of public interest, will not exist in great quantity until LUVO. In response to a question, Green said the mission could be scheduled for 2024 or 2025.

Steve Kahn noted that members of Green's team were also on an Origins Probe study and others; how did Green explain that? Green said it emphasized the importance of the field. Kahn commented that it appeared to him to be the same people 'throwing their hats' at similar concepts; might an Origins probe be sufficient? Green replied that he thought it better for people

to ‘back more than one horse.’ He would not want to stake everything on the Origins probe line. If this committee recommended an Origins probe in this area, he would be delighted; such a probe, he added, would in his view strengthen rather than lessen MAXIM. Kathryn Flanagan asked whether Green was saying his group would like four chances at getting one probe. Green said that, speaking solely for himself, he would.

Single Aperture Far Infrared Telescope [SAFIR] – Dan Lester
If executed, Dan Lester said, SAFIR would be a probe of cosmic beginnings. The project, he noted, was involving four NASA centers and had been endorsed by the decadal report. He said he would focus on the project’s merits: SAFIR would resolve the FIR background; probe the earliest epochs of metal enrichment; track the chemistry of life, and identify nascent solar systems from debris disk structure. He noted that the project’s technology requirements – large science arrays and spectrometers; low temp passive cooling; efficient, long-lived cryo-coolers; deployable large aperture architectures – were common to many other missions. He noted that the study group was looking at possible servicing by astronauts and robots. Kathryn Flanagan asked about the similarities between SAFIR and SPECs. Lester replied that SPECs offered greater resolution, was a much more difficult mission and should be done after SAFIR.

Advanced Compton Telescope [ACT] -- Steve Boggs
Advanced Compton Telescope is intended, Steve Boggs reported, to uncover how supernovae and other stellar explosions work to create the elements. ACT offers a 100-fold sensitivity improvement for spectroscopy, imaging and polarization. He noted that, among other things, ACT tied to 2003 Space Science strategic objective 5.12 – “understand the development of structure and the cycles of matter and energy in the evolving universe” and had been identified in the 2003 SEU roadmap as to be “undertaken after Beyond Einstein has begun.” ACT would, Boggs said, open the sky to a great deal more discovery space; hundreds of sources. The comment was made that too many technologies had been considered, ranging from very mature to those needing much further development. The need is to shake this down. Robert Stern asked why this project was classed as a Vision mission instead of a probe. Michael Salamon responded that it had been brought forward in response to a call for vision missions. Kathryn Flanagan asked if the project could be done within a $600 million cap. Boggs replied that he thought so; it had been costed out at $700 million. Flanagan noted that in 1995 and 1999 ACT had been identified as the highest science gamma ray mission. There was, she added, some doubt as to how the project was to be accomplished; the next question was to settle on an approach.

Stellar Imager -- Ken Carpenter
Stellar Imager is a UV/optical deep space telescope for 0.1 milli-arcsec imaging and spectroscopy of magnetic field structures that govern the origin and evolution of stars and planets; the habitability of planets; various transport processes and solar system space weather in the current era. The project was needed for the better understanding how magnetic fields form and evolve. Physically, Stellar Imager would employ 20-30 tethered mirror elements. The presentation included discussion of a precursor mission in 2015; the full mission to follow in 2025. Asked about test missions, Carpenter said these would be done on the ground, though it was as yet uncertain how. He noted that other missions faced this issue. Anne Kinney asked what overall budget was foreseen; Carpenter declined to answer off the top of his head. Michael Shull asked whether Stellar Imager would be able to separate out planets; Carpenter said it could, if they were far enough out.

Far-IR & Sub MM Interferometer [SPECS] – Martin Harwit
The Far-Infrared region, Harwit said, conveys half the energy and 98% of the photons ever generated in stars; SPECS will capture information on this. With SPECS, two light collectors will

convey compressed collimated beams to a central beam combiner. SPECS will measure merger dynamics, red-shifts, and physical/chemical conditions in the interstellar medium to probe galaxy formation and evolution with information complementary to that available in the starlight seen by JWST. The major technology requiring study, Harwit said, is the long tether; a larger scale effort was needed to check out direction and control of the small telescopes. Additional pointing studies were needed with the main telescope; it was fairly complicated, he said, but no real problems were foreseen. The metrology required was industry standard. Steve Kahn asked why tethered flying was crucial: Harwit said because it was not possible to carry into space sufficient propellant to use thruster corrections. He added that he believed SPECS would do 300 re-positionings a year; in one day it could cover the entire baseline from one kilometer down to 10 meters.

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DISCUSSION OF VISION MISSIONS
Led by Nicholas White

Nicolas White noted that the committee would be discussing far-term strategic objectives. If an objective is selected, a mission will follow. This discussion did not raise conflict of interest questions, as no strategic partners had as yet been identified. Kathryn Flanagan asked whether it was permitted to recommend specific missions. White said it was, because identifying science questions and missions did not specify agreements. Steve Kahn commented that he foresaw problems if the group sorted between the Beyond Einstein and the non-Beyond Einstein projects; a holistic approach was better. What was needed was a common story that included all the fundamental physics that relates to stars. Attention should be paid to how these missions could be coordinated with efforts outside Universe Division. Michael Salamon said the group had a strategic objective: it needed to find science objectives; those objectives were the elements of a story. Missions should be mapped to that story, rather than the reverse. Michael Shull noted that 2025 was not so far off and the group needed to be realistic about what might be possible. Ron Polidan said the capabilities groups would benefit from a better definition of what would fall in the 2010-2020 range. Steve Kahn noted that some things were pushed beyond 2025 for budgetary rather than capabilities reasons.

The key question, Anne Kinney said, was what were the highest priorities in terms of science; start with the science and then fold in the technology. Robert Stern noted that at times the highest science goals were simply undoable, so it did not matter if they were prioritized. Sterl Phinney said there was both a science strategy and a packaging strategy for securing funds; money is a serious object. Everything will be done on a flat budget, in which case of lot of this will not be done by 2025. Steve Kahn said it was a problem that Universe science did not have a set budget. Anne Kinney listed the missions currently under budget, with their launch dates:

GLAST – 2007
Hersul – 2009
LISA – 2015
Constellation-X – 2017
Probes – 2019; 2021; 2024

Kinney noted that NASA was one of the few agencies with a long-term budget; the group could assume the budget would be flat. Steve Kahn noted that the dates given about might not hold; unless, he said, we come up with a logic why 2015 is reasonable instead of 2019, we have a problem. Other roadmaps have interconnecting lines that show the consequences if something is delayed. Anne Kinney agreed, noting that the most powerful thing about Origins was that it was interconnected by a scientific logic. Jakob van Zyl argued for making scientific connections between various things; he added that science was what drove things. Anne Kinney noted that JWST was funded because it was considered top priority science. Steve Kahn sketched a possible story line: set down the fundamental laws of physics that govern the universe and use

that as a way of motivating what you do. Con-X moves from strong gravity to emergence of structure issues; you could, he said, almost make an engineering story. Sterl Phinney noted that there were complementary ways of doing the same thing; JDEM might run into problems with evolution so it might be good to have a test first.

Anne Kinney said the group needed to address a strategic plan, and act within a best-case scenario of what is sound science for government investment. Michael Salamon noted that decision points were needed; there might be a number of ways to attack the science; alternatives should be identified. Nicholas White noted that the group had heard eight presentations; it needed to say yea or nay to whether these missions fit our scientific intentions? If so, the committee will review them individually tomorrow. Michael Shull said that all fit the science goals. The group should consider which of the things contingent for their success have not yet been accomplished. BBO is contingent on LISA; first generation projects should be focus of immediate concern. Kathryn Flanagan said she had checked other roadmaps to see what they might have overlooked; maybe the group should lay claim to those. Michael Shull asked if there was a downside to leaving something off, as opposed to making it low ranking; the committee certainly should not say everything was equal. Kathryn Flanagan said she had sought, but not received, direction on how the group could prioritize strongly; it needed to be able to give emphasis. Anne Kinney said she saw nothing as more important than prioritizing. Sterl Phinney said there was interest in magnetism; we do not know how the solar corona is heated, but he did not see that having more pictures will be particularly helpful. Nicholas White suggested considering the Vision missions by time frame; Anne Kinney added they could also be framed by mission size. Sterl Phinney commented that Gen-X, SAFIR, SPECS were principally directed at the first stars; a science story could be tied to that. Michael Shull suggested that this could be rephrased as initial conditions and the emergence of structures. Kathryn Flanagan noted that Beyond Einstein split between the fundamental physics and the later activities. Ron Polidan said the group needed to focus on the technology challenges as some of what it wished to do was not doable for ten years. Discussion ensued on possible coordination with SRM-4.

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PUBLIC COMMENT AND GENERAL DISCUSSION [Tuesday lunch]:

Martin Harwit advised the committee against associating missions with cosmological boxes. Many things have been learned from x-rays that have nothing to do with massive stars, he said. Most of the Universe missions have broad appeal: some will do chemistry, which he believed would become a new subfield of astronomy. The urged thinking about missions in general purpose terms. Years ago, he added, a similar problem had occurred in astrophysics: a number of expensive missions were coming up and Congress asked why did the group come in each year with another mission? The response had been to come up with a 'comic' book of how different missions complemented each other and were directed at particular energy ranges. Congress accepted that approach. Perhaps the committee should attempt a similar approach if it showed how these long-term missions would complement each other and should be done as money became available.

Anne Kinney said she doubted that organizing missions around wavelength distinctions would work today. Harwit responded that the argument should be framed around complementarities; clean lines might not result, but they would appeal to a much broader community. Kinney asked on what basis prioritization should be based. Harwit responded: technological readiness. Kathryn Flanagan noted that the committee also would be recommending technology developments, which itself helped determine technical readiness. Harwit responded that he thought it was very difficult to say that one scientific problem is more important than another. The universe is so interconnected, he added, that it was difficult to say today which observatory will be solving the problems that will be of importance 20 years from now; all that can be said is that these are the problems known today. Michael Shull commented that he was an admirer of the notion that big advances in technology drive science. However, the committee's task was to come up with the science questions. Harwit said that while looking for

pre-mission scientific justification made sense, when a mission actually flew it would answer questions beyond those being posed.

Anne Kinney restated that the committee was obligated to proceed on the basis of science questions for which answers were being sought. Steve Kahn observed that radio observatories proved that you cannot predict the answers you will get. It was not clear, he added, that NASA believes the Universe division exists by right; the division must look important in mission terms. The phrase 'discovery space' which underlay Great Observatories is no longer much used because it was too indefinite about achievements. That a given mission crosses topics is to its credit, he added, but the group needs to present the mission in terms of the few things that make its case. Harwit asked how prioritization could occur: on the basis of science? the path of least technological resistance? He added that similar problems had been faced 20 years ago. Ron Polidan noted that it was part of the charter of the capabilities committee to look at the science and then assess technological readiness.

Steve Kahn said the committee needed to create an ordering for missions, not necessarily a time ordering; otherwise, it might suggest it did not care what it did. Anne Kinney suggested that what was needed was the underlying story. Comment: No harm in connecting the two approaches: time order, up to the creation of the modern universe; and mission order, the sequence of execution. The committee needed to be somewhat practical: it would be unwise to say that some academic science question was so paramount that the group did not care if it took 30 years to accomplish. Anne Kinney responded that if the prioritizing became 'mushy,' then the group's case was weakened; the stronger the prioritization, the likelier that the sequence sought would be approved. Comment: When the Universe SRM is added to the others, one question will be: how well do the missions the roadmap proposes address the intentions it announces. The roadmap can't just say: this is the most important science we see; it has to say this is how a particular NASA objective can be best addressed. He added that he thought metrics will be important, because the integrating will primarily be done by engineers; the better things are presented as proceeding toward a wanted goal, the better you sell your program.

Anne Kinney commented that a strong prioritizing was the best path; she added that this was difficult as people would rather make friends than enemies. Steve Kahn said technologies developed in two ways: one was incrementally; the other was technologies developed because a particular mission required them. Kinney added that she favored creation of a competed line with three smaller annual projects followed by a larger one. The question was raised how the Discovery line was sold. Comment: It was presented as a way to do better things after the failure of Mars Observer.

Sterl Phinney asked what creation of such a line would take. Anne Kinney estimated it would require taking about $260 million from the division budget of $1.5 billon. She added that almost everything the division did was large and strategic, and subsequently slow. A competed line would provide a tempo. Steve Kahn noted that Explorer had been open ['competed'] on every round. That had some advantages, but concepts that were not selected tended to resurface later, often multiple times: people change the acronym and reapply. This, he said, was a waste of time and money. It would be better to compete on the basis of a specific priority concept; one will win, others would lose, and that would be the end of it.

Comment: This was done in some other groups. The New Frontier line was more recently open to only four concepts, with the decision made on the basis of strategic plan, community input and their perception of what was ripest. With Explorers, he added, the turndown rate was 15 to 1. On the topic of moving money to a competed line, Anne Kinney commented that LISA and Con-X had little current funding; to take an appreciable amount from them would kill them without providing much funding to anything else. Comment: Freeing up $260 million would mean take 1/6 out of everything, including research and analysis, etc. Kinney added that as SOFIA, GLAST and Hubble were 'fenced off,' the share would be closer to 1/3 of everything else.

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REPORTS ON EINSTEIN PROBES:

CMB Task Force Report-- Rai Weiss

The basic questions, Rai Weiss said, were: How did the universe begin? What is the fundamental physics? How did the universe evolve? One approach to these questions was provided by inquiry into Cosmic Microwave Background [CMB] radiation. CMB was emitted immediately after the Big Bang and provides evidence of the Dark Energy believed to be pulling the universe apart. The committee was advocating further study through a combination of ground-based and balloon-based activities, along with a CMB probe. Weiss described the space-based effort in detail and outlined the technology challenges the mission faced; there were also, he said, sensitivity and foreground issues to be resolved.

Steve Kahn said the recommended program was heavy on ground-based observation; he thought fundamental questions still exist about the foregrounds. Rai Weiss replied that there was less interest in foregrounds; most people believed that modeling could produce good projections. Still, one wanted to be sure of that and to know what channel to pick: people did not want to get to the 100-nanoKelvin level and not discover something new in their instruments. Kahn asked, if basic research questions were currently unresolved, could this mission actually be roadmapped? Weiss replied they assumed the answer would be known by 2012, the launch date they were looking to. That date, he added, had been chosen by people familiar with the issues. Michael Shull asked whether the entire sky would be viewed. Weiss responded not the entire sky, but most. More generally, he said, it was possible to do high resolution 'small stuff' from the ground. Not everyone was in love with spacecraft, but there was a good combination: use a ground based effort to design for space; use space because it is so quiet. Shull asked if mapping the foreground had to be done in space; Weiss responded that that was preferable but not necessary. Nicholas White asked how large a dish the task force was considering. Weiss noted that two options had been presented: a 1 degree beam and an 0.1 degree beam. For the 1 degree beam, the size would be two meters. The required size of the dish will be easier to determine when more information is in hand on the proper frequency to use: for example, if 70 gigahertz is best, then a 35 gigahertz channel might not be included, making the dish smaller. Weiss said the difficult piece was to get the energy scale: what is the rate of that expansion? Sterl Phinney commented that if the energy scale was very large -- just under Planck – that it was fairly obtainable; otherwise it would not be easy.

JDEM SDT Report -- Charles Bennett

Joint Dark Energy Mission [JDEM] is a NASA/DOE project to help determine the nature of Dark Energy, in part through a space-based mission. SDT is the Science Definition Team convened to develop findings on this topic. Opening his status report, Charles Bennett said that of the 11 questions posed by the National Academy of Sciences, Dark Energy was the most vexing. Its resolution would greatly advance understanding of matter, space and time. The National Science and Technology Council had urged that multiple, complementary and independent approaches be used, including a dedicated space-based experiment to precisely measure the nature of the Dark Energy and its evolution over the history of the universe. Bennett outlined his team's schedule, tasks and responsibilities. Bennett identified a series of yet to be resolved issues: it was nearly impossible to set a top level science requirement; as there are not two, but many, theories of Dark Energy, it is not possible to test for a specific hypothesis; no set of parameters was 'best' for all types of Dark Energy; it was difficult to know the level of improvements JDEM required in such areas as baryon oscillations, weak lensing and others. The team needed to decide whether to take a general v. a specific approach; use a single v. multiple techniques; whether the mission should be self-contained or operate in junction with Great Observatories. Finally, he said, there were some DOE/NASA joint management questions. The team would continue to meet and write; construct science requirements and technical guidance for NASA/DOE, and remain coordinated with the roadmap groups.

Steve Kahn asked how wide a class of science could be accomplished by a single mission. Bennett said that at this point, in terms of the science, no one can answer the question of how good it should get. The idea that JDEM might be a general purpose wide-field telescope in space is a possibility, but not one the team encouraged. There is a choice, he said: the mission can be more general and cost more, or more focused and cost less. Steve Kahn asked

how the JDEM mission would be compromised by undertaking other science. Bennett observed that any time devoted to doing something else was a cost against intentions; if, however, JDEM was still operating past its design life, that would be different. Comment: Believe that after the Dark Energy work is completed, the telescope would be available for general use; that is the least expensive way to get general astronomy. Bennett said his team had a strong sentiment against designing JDEM to have operational modes not intended for Dark Energy; they did not wish to complicate the issue. Blackwood commented that this had also been an issue in GLAST. Kahn added that the 'science share' challenge was not so much for JDEM as it is for other missions that have less focus. Kathryn Flanagan asked how soon the team would make a formal recommendation. Charles Bennett said there was no formal deadline, but he believed in two years.

Black Hole Finder Probe [BHFP] -- Neil Gehrels

The primary scientific mission of the Black Hole Finder Probe (BHFP) is to survey the local Universe for black holes over a wide range of mass to learn about the accretion rate. Two study teams are engaged in concept development, Neil Gehrels said: EXIST [Energetic X-ray Imaging Survey Telescope] and CASTER [Coded Aperture Survey Telescope for Energetic Radiation]. The former has been around for a long time, Gehrels said; a large international team has been working for more than five years. He described the status of the work and the scientific thinking that underlay it. He said BHFP would find tens of thousands of sky sources, as opposed to the hundreds noted now. BHFP, he said, would cover 30-40 percent of the sky. He felt BHFP was similar to the GLAST mission in cost range. Gehrels said the major technological need was ASIC development: considerable progress was being made in this area. He added that Black Hole Finder ranked highly in the decadal survey. Charles Bennett asked if the purpose of the mission to determine how many black holes there were in an area or to follow up on other work. Gehrels said both were needed. In closing, Gehrels said that BHFP would conduct high priority science. The basic technology was in hand; new detector technologies were giving a high sensitive jump, similar to GLAST in jump and cost. Gehrels said he believed the mission could be ready to launch in 2011.

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ORIGINS PROBES: Eric P. Smith

The rationale for the Origins probes, Eric Smith said, was the belief that the division was top-heavy in flagship missions and lacked a competed line. In February 2004, the community was asked what missions could be done in the $600-700 million range. In fall 2004, nine mission proposals were selected for concept studies. Those selected were:

ASPIRE: astrobiology
BLISS: a collaborative effort with Japan
BSP: to detect, map and characterize the cosmic web
Cosmic Inflation Probe: to develop better information on the physics driving inflation
Galaxy Evolution Probe: a surveying tool [Steve Kahn asked if the same science could come from JDEM; Smith said that it could. Sterl Phinney commented that JDEM did not go to the same infrared range as GEP].
Hopkins Origins Probe: a competitive alternative to a manned or robotic HST mission. [Kathy Flanagan asked if this project fell outside the price range; Smith said it did, having been quoted at $700 million to $1 billion]
HORUS: [High Orbit Ultraviolet Visible Satellite]
OBSS: [Origins Billion Star Survey]
SPIRIT: to learn how planetary systems form from protostellar disks and how they acquire their chemical organization

[Full presentations on each are available at: http://ese-dropbox.hq.nasa.gov/ese-dropbox/]

Commnet: The original intent had been to seek science that could be done in the $600-700 million range; most of these fell in the $1 billion range. Sterl Phinney said the way to get $600 million missions was to ask for $300 million proposals. Michael Shull asked if NASA planned to put these missions into a single document; Smith said that was under consideration. David Leisawitz took issue with the cost statement; his proposal had been carefully costed at $450 million, which with the launch vehicle made $600 million. Michael Shull asked if NASA headquarters felt that because Einstein Probes were invented first, they should go first. Michael Salamon said not necessarily.

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GENERAL DISCUSSION OF PROBES:
Led by Nicholas White

Nicholas White posed several questions to the group: did it want a specific Universe probes line? Should existing activities be 'taxed' to fund such an activity? What should be done about Opt/UV in the Post-Hubble Era? It was noted that currently approved missions were SIM, LISA, Con-X, GLAST and the probes. Steve Kahn said he was not concerned that the Einstein probes didn't launch until 2019; Big Bang Observer was exciting and required different capability. He did not feel the same about projects of lower science magnitude. If something was clearly 20 years off, it should be left out of the roadmap so that decision could be made on the basis of where things stood in 20 years. Robert Stern said that if the committee said 'no,' certain fields would cease to exist; people would gravitate toward funding. Michael Shull noted -- on 'taxing' existing programs to finance a probes line – that, given the projects that were 'fenced off,' it would require taking one dollar in three from everything else. That would make it necessary to cancel a mission. Steve Kahn commented that the group could commit to the probes concept without committing to particular missions. He added that missions slated for 20 years hence should be 'visionary,' not relatively small extrapolations over what was already doable. Some missions were being termed visionary not because the science was far off but because the funding was far off. Kathryn Flanagan asked Kahn if he preferred scheduling things only a few years in advance. Kahn said yes, though he regarded the Einstein Probes as an exception given the quality of their science. Charles Bennett said that taxing a program by one-third was tantamount of canceling it.

Eric Smith was asked the original reason for the Origins probes. He said the 'Origins side of the house' had seen utility of the Einstein probes – science goals and medium budgets – and wished to see if it could make a similar case. Jakob van Zyl commented that if the underlying probe concept was a piece of science significantly smaller than full missions, it should be less expensive; probes were appropriate if there are compelling science questions that a smaller technical effort can achieve. Van Zyl said he supported creating a probe line, but perhaps not in the next 5 to 7 years. Ron Polidan supported a probe line, saying that when a series of large missions was spread out over time, the skills needed to build instruments and other support activities atrophy: with better mission focus, industry could get a better response.

David Leisawitz took exception to the statement that the Origins probes proposals were mere extrapolations; he had found the presentations impressive. Without probes, the division would be doing nothing that fell between $250 million and $2.5 billion in budget; he felt there was a lot of good science in that range. Michael Shull commented that this was a longstanding point of discussion. Robert Stern suggested that killing a mission was a bad idea, as they were all so far along. Nicholas White noted that no consensus had been reached: some favored establishing a probes line now, others did not. White noted separate proposals for Origins probes and Universe probes; if these were combined, would the Einstein probes be first priority? Michael Shull said that any merging should be done now; once the Einstein probes were started, merger would be more difficult.

Kathryn Flanagan noted three things: first, the idea of probes has been successfully introduced; they might be added in either SRM-4 or SRM-8. The division should be able to insert missions of the appropriate size. Second, she considered the Einstein probes a better concept:

targeted, accepted and approved. The group could add probes without calling them Origins probes. Third, was the group going to do big missions but carve out money to do the smaller missions more rapidly? That would involve canceling something; she did not favor canceling anything in favor of something that had not yet been approved. Steve Kahn commented that while, philosophically, the idea of $600 million missions was attractive, funds did not exist. Were there compelling science questions – questions on a par with Dark Energy – that the three Einstein probes will not accomplish? If the group had a $600 million mission it would like to do today, but which, because of funding, can't be done until 2029, why bother? Ron Polidan observed that this led back to the question of what science questions the committee wanted to answer.

Sterl Phinney commented that most of the proposed Origins concepts could be 'smuggled' into Einstein; the qualitatively different one was the Billion Star Survey. The suggestion was made that Cosmic Web Survey might be another exception. A number of the Origins proposals, Steve Kahn said, appeared technologically ready; it seems odd to advocate something that is ready now to fly it in 25 years unless it is truly visionary. David Leisawitz commented that the projects would not be mothballed in the interim; technology improvements would be incorporated. The real question was whether high scientific return could be had from missions priced at between $250 million and $2.5 billion; if the committee agreed that good science can be done for $600 million, than proposals would surface. Nicholas White expressed agreement.

Steve Reinhart commented that there were many things that would not be learned for 20 or 30 years unless smaller missions went forward now. An audience member associated with the SPIRIT proposal said he would gladly repost the science objectives for his mission to show that they met the criteria for important science; in combination, he said, the Origins probes offered an enormous amount of good science. Michael Salamon directed several comments to the group's process: he felt things were being put in reverse order by discussing each mission's capabilities rather than starting with the science questions they were intended to answer. The group needed to sketch out a very compelling line of science objectives; he suspected that some of the discussion of particular probes was not productive toward that end. Robert Stern said the basic point was that the group must justify on the basis of science.

Discussion turned to ultraviolet capabilities. Michael Shull commented that UV capability was needed because that was where the baryons are; the highest density of resonance lines are in the UV. Steve Kahn saw a lesser importance. There are times, he said, when things have to end; UV science was not over, he said, but new science will not get done unless some things are set aside. Perhaps the group should consider how valuable optical science in the $600 million mission range was. Michael Shull commented that he thought Cosmic Web was a 'killer application.' Michael Shull suggested that Cosmic Web could be done on a scaled-down basis. Ron Polidan commented that if there was a mission class in the $300-500 million range, it would provide safety valves to spin off some ideas.

Nicholas White asked the group what it wished to see happen with probes – Einstein, Universe and Origins. Ron Polidan suggested initiating such a line around 2010. Robert Stern suggested the group maintain the option of addressing science questions through probes; he was uncertain about the technological readiness of a number of the probe proposals. Sterl Phinney said he was all in favor of a probe line and of doing whatever was possible to accelerate one: the science case was damaged by delaying them until 2019. He thought the best strategy was to retain the Einstein Probes, with the understanding that revisiting would occur every three years. Jakob van Zyl commented that the Einstein probes were associated with specific science questions; the Origins probes, however, were prompted by a query for ideas rather than by an identification of compelling science to be addressed. Charles Barnett expressed agreement, adding that the Einstein probes were always presented as a 'line;' that had value; perhaps that line could be added to if a suitable science story was prepared.

Kathryn Flanagan said the group could establish unnamed probes, deciding the specifics in the future. Steve Kahn expressed general agreement; he suggested the focus of the Einstein probes should be altered to provide a better fit with the strategic roadmap process. He found it discouraging that probes were being pushed past 2020; the science issues are very pressing

now. Any probe line should be targeted to science questions; within the Origins proposals, only Cosmic Web had really high allure. He added that the group had to be concerned with technology development. Ron Polidan said the group should be aware that many technologists were looking to the SRMs for prioritization so they will know on what they should focus. Michael Shull said he was depressed by the inability to get to the exciting work in progress; relative to missions, the group needs to be able to say: just because a mission is big doesn't mean it goes first. He hoped some means could be found to break the logjam created by the 'blockbuster' missions. He said he was concerned about SIMS and concerned that TPF had 'metastasized' into two ~ billion-dollar missions.

Reviewing the day, Kathryn Flanagan said the group had made serious progress, but was yet to bridge the gap into bigger concepts – the visions – nor had it bridged the gap between spacetime issues and structure and evolution. She added that the group could not leave on Wednesday without these being resolved. Nicholas White asked for two individuals to consider the Origins probes further. Robert Stern and Sterl Phinney volunteered. The agenda for Wednesday, Nicholas White said, was to determine how all the Universe activities could be fit into a story that would form the basis for the roadmap.

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Session of Wednesday, March 16

PRESENTATION ON EDUCATION GOALS – Roy Gould

Roy Gould called attention to twin goals in education: to encourage students to pursue science and to educate the public. He noted that many of the scientists who will bring currently discussed missions to fruition were now in grade school. He noted that the activities of the Universe Division were central to NASA's national education goals. He added that students currently exhibit a great deal of ignorance: one survey of 7000 middle and high school students showed that most put the stars inside the orbit of Pluto. Many teachers know little more than students. Students and teachers were unfamiliar with the universe beyond the solar system, possibly because the standard eighth grade science curriculum did not go further than that. Universe missions involve compelling educational stories, he said [Black Holes; Big Bang, Dark Energy, etc.]. One current priority includes the development of learning tools, national partnerships with museums and others, scientific visualization and strengthened support for undergraduate education. A second priority is to permit students access to real research, including on-line telescopes and other steps. There is, he added, great public interest in Universe subjects, demonstrated by PBS and other broadcasts; the Cosmic Questions exhibition; the 100 museums collaborating on Inside Einstein's Universe; and such informal activities as the After-School Astronomy Association.

Steve Kahn asked if better coherence might be achieved if education efforts were centralized rather than mission-by-mission. Gould replied that the mission-by-mission model ensured scientist participation. Michael Shull urged that retirees and others should be encouraged to participate. Sterl Phinney asked how the activities associated with Universe SRM activities compared with other SRMs in public interest. Gould said there was likely more interest in Mars, but that Universe ranked high. Craig Hogan asked about 'filling the pipeline' by NASA. Comment: NASA's office of education has a number of programs that are not well coupled; the former NASA administrator initiated a great many programs; these now need to be integrated. Michael Salamon noted that the group's final roadmap report was to identify unique educational and outreach opportunities. Roy Gould commented that education efforts would be aided by a greater definition of what the stories were. Kathryn Flanagan raised a concern: the Universe Division had future needs for instrumentalists to work on technology. Can the final SRM incorporate that? Gould said that was entirely appropriate. Louis Barbier commented that each of 12/13 NASA regions currently have an education facilitator; the group already has access to these people.

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APIO WHITE PAPER ROUNDTABLE
Led by Kathryn Flanagan:

Kathryn Flanagan noted that the group had received about 20 White Papers in November. These had been posted on the website and Flanagan sought the group's comments on each [appreciable comments are recorded]. Robert Stern noted that the White Papers covered a scattershot of things; what was the general philosophy for soliciting them? Nicholas White said that were a check to make certain the group had not missed something of consequence. Kathy Flanagan said the White Papers collectively included some in a mission context, some advocating technology development and some that were science concepts that might be worthy of attention.

A New Window on the Universe: The Case for Enabling Ultra-High Energy Neutrino Astronomy – Robert Streitmatter. Sterl Phinney noted that the Universe Division had selected this one for consideration.

Boeing NASA Systems Response: Exploration of the Universe – Boeing. Ron Polidan noted that the content of this proposal was explicitly covered in the Observatories work and was part of the recommendations for Capabilities RM-10.

Coupled Physical/Chemical Evolution of Protoplanetary and Protosatellite Nebulae – J. Cuzzi

Dual Purpose Mission: Diffuse Gamma Tray Background Explorer and Long Term Monitor of the Cosmic Ray Flux – Jacob Trombka. Sterl Phinney noted that this had been an Explorer proposal.

Focal Plane Sensor System Development – C. Bebek. Ron Polidan suggested that the instrument capabilities group be queried to see if this was of interest to them. Steve Kahn noted that two issues were involved: packaging sensors and achieving depletion.

Future Tests of Gravity Using the Solar System – T. W. Murphy. Comment: The topic of White Papers was a good place for crosstalk between roadmap groups. There was, he thought, an opportunity to fly Universe payloads on missions to other planets.

Integrated High Energy Mission – J. Kurfess. Steve Kahn said this White Paper related to an implementation question and comment was not needed. Comment: If the group decided to say something about this, it should be placed in the context of Tuesday's discussion about modest-sized missions.

Investigation of Interstellar Matter at Sub millimeter and Far-Infrared Wavelengths by High-Resolution Spectroscopy – Anders Skalare. Charles Bennett said he believed there was an Explorer proposal along the same lines; he would support development of the technology.

Laue Lens Gammy-Ray Spectroscopy Mission – Cornelia Wunderer. Michael Shull asked how this represented an improvement, saying it might be a Vision mission beyond ACT. Ron Polidan noted that it was currently not in future technology. Charles Bennett said this again pointed to the problem of the process happening backwards -- technologies being recommended that don't match missions in the roadmap.

Micro calorimeter Arrays for Imaging X-Ray Spectroscopy of the Universe – C. Kilbourne

Probing Fundamental Physics and Astrophysics with X-Ray Timing of Black Holes and Neutron Stars – Deepto Chakrabarty. Steve Kahn commented that this one should not be dismissed; the group could not roadmap the science topics of Explorer, but it could validate techniques without making mission decisions. Comment: The one thing the group could do was to call out certain science areas as of interest, but add that the science can be achieved through modest missions. Steve Kahn disagreed, saying he thought the group should make a definite statement; either put a proposal in the program or decline to. He asked whether this proposal's costs were similar to ACT. Nicholas White said it had been framed as Explorer class. Robert Stern noted that proposals not placed in the roadmap might still be attractive to a peer review group. Jakob van Zyl said the group could recognize it as important science and leave it at that. Charles Bennett asked if it was a potential Einstein Probe. Sterl Phinney said he thought this was another example of talking about a near-term mission that won't be done for 20-25 years. Kathryn Flanagan said the committee could say it believed the proposal had merit, but did not regard it as more important than what it might replace.

Research on SOFIA Upper Deck in Support of the Vision for Space Exploration – Peter Jenniskens

Sounding Rockets in the 21st Century – Stephan R. McCandliss. Comment: Doubt much more great science could be done by putting an astronomy payload on a rocket; the proposal made more sense for student training than as science. Michael Shull said that student training was not the only important concern; a second was hardware qualification. Charles Bennett said the group should not think of this as only student education. Steve Maran stressed the importance of training: NASA, he said, was trying to develop the next generation of explorers. Classroom study was not enough; hands-on experience in space flight was needed, so there would be people in 25 years to do the missions now being discussed. Training through balloons and other suborbital programs was, he thought, extremely important. Steve Kahn commented that because this group grew up with rockets, it assumed that fundamental science was related to rockets. The problem was, if you support this, then you support this against other things. He said it was currently a problem to find students to work on real satellites; to say because we have rockets we're going to get students was not true. Steve Maran commented that the number of students that could be trained on satellite projects was far lower than on rockets. Michael Shull commented that at his university students were clamoring to do rocket work.

Strategic Objectives White Paper – Dan Lester. Kathryn Flanagan said this paper had been of interest to Universe Division; she thought much of the language was appropriate intellectual terminology.

Summary of Laboratory Astrophysics Needs – Scientific Organizing Committee of NASA 2002 Lab Astro Workshop, Farid Salam [chair]. Kathryn Flanagan noted that there had been some interest within the Division on this.

The Advanced Compton Telescope – S. Boggs

The Effect of Radiation on Collision Process and Analytical Analyses – Unknown. One committee member recommended referring this paper to SRM-4.

The Future of High Angular Resolution X-Ray Astrophysics – Michael Kowalski. Sterl Phinney commented that the proposal was very visionary.

The Under-utilized Window: Extreme Ultraviolet Astrophysics – Michael Kowalski. Kathryn Flanagan noted that this paper had received a lot of interest from the Universe Division; it falls under the category of generic science. Steve Kahn noted that it was generic, but not sufficiently specific. Michael Shull said he was concerned that the window one could see through with UV was relatively small.

White Paper on Laboratory Astrophysics Studies – Farid Salama. Committee referred this paper to SRM-4.

White Paper to Address NASA Strategic Objectives Focus Area 7 – Melville Ulmer.

White Paper to Address NASA Strategic Objectives Focus Areas 7 and 4 – Melville Ulmer.

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BEYOND 'BEYOND EINSTEIN' – Sterl Phinney

Einstein, Sterl Phinney said, is best known for his theory of relativity and his introduction of the dark energy concept. The legacy of this theory has left three fundamental questions unanswered:

1. What powered the big bang?
2. What happens at the edge of a black hole?
3. What is the mysterious Dark Energy pulling the universe apart?

The NASA Beyond Einstein program is seeking answers to these questions. Phinney then reviewed the Big Bang, the subsequent growth of structures and the interaction of light with matter. Additional questions need to be posed, including:

4. How did energy and light from structures in the universe mold those structures into those we see today?
5. How does Dark Matter form structure and hold galaxies together?

Question 4, he noted, replaced Question 1, 3 and 4 in the Universe legacy roadmap. He noted that a number of missions were related to question 5, including: BLISS, OBSS, SPIRIT, CIP, HORUS, HOP, ASPIRE, BSP and GEOP. He added that questions 4 & 5 were not matters he would advise taking up with a Senator in an elevator; for that, 'sexier' phrasing was needed. Steve Kahn noted that there were so many aspects to Dark Matter that it could tie to a great many proposals and missions. Phinney commented that how structure was formed was multifaceted; one could address one piece of that without addressing all of it. Kahn suggested the alternative was to narrow questions until they become answerable. Michael Shull said that made them less interesting. Phinney asked who the audience was: the Senator or the NASA panel. Craig Hogan suggested that the high level questions would be the same for all; at lower levels they could be stated differently. Considerable discussion ensued on the proper wording of Question 4 and the eventual deletion of Question 5.

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INCLUSION AND PRIORITIZATION:
Led by Nicholas White

INTEGRATION PROCESS – Steve Kahn
Steve Kahn posed the question of how the committee should structure its plans so they would be relatively secure during the integration process. Universe missions were at a disadvantage, he said, because they were relatively uncoupled with other roadmaps. He noted Marc Allen's comment that NASA was seeking to create an agency-wide PERT chart. Such charts were useful because they provided a schedule. NASA, he thought, would use the final plan to provide a schedule with decisions not being made on the basis of scientific or technological interest. The group's challenge was to create causal and time-ordered connections between its missions. This was tricky, because it links development schedules to things outside the group's control; further, it runs counter to the established idea that things should be tied to readiness, not to the attractiveness of the science.

Kahn called attention to several statements in the Aldridge Report. First, NASA seeks input on 'exploration architectures' and, second, it sought 'discovery based criterion' for selecting destinations beyond the moon and Mars. The first was 'PERT-like;' the second wasn't. The group, therefore, needed to propose an architecture for discovery. Universe Division, he said, needed a story that acknowledged two constraints: first, it needed to make intellectual sense; second, it had to be consistent with the time ordering the group envisioned for its missions. He thought satisfying both requirements was difficult. He believed the answer needed to be multidimensional [multiple PERT charts]. He urged the group to work around two fundamental thrusts: first, the group wanted to explore the structure of spacetime; second, it wanted to understand through exploration how things proceeded from quantum fluctuations to life. Comment: Note that the PERT chart need not be linear; other SRM groups had fairly complicated charts. Kahn noted that if the group adopted as an organizing principle the statement that Universe division was proceeding from the solar systems toward increasingly primitive structures, it fit better with the mission sequence.

INTEGRATION PROCESS – Charles Bennett:

Charles Bennett presented a graphic showing years to 2035 as the left-hand axis and stages of life [Big Bang, Inflation, etc.] as the horizontal access, with the individual missions located to show their timing and interactions. Sterl Phinney commented that a spacetime component was needed. Bennett replied that he doubted spacetime would "sell" – it was popular with those in the room, but not outside it. Comment: there appears to be a lot of missions; perhaps graphic clarification could show that 50 years was involved. Phinney suggested overlaying two PERT charts of sets of ideas, then drawing vertical connections between them; one way of combining them could be to see the top as having boundaries of space and time, then you do the complicated science. Nicholas White emphasized that it was necessary show decision points.

Craig Hogan said he preferred Steve Kahn's presentation, as more flexible: the idea of proceeding to the more primitive, to the edge, had narrative possibilities. Kathryn Flanagan said that the vertical column appeared to be divided by wavelength; was there a risk that this might appear to be 'stovepiping.' Sterl Phinney suggested a model in which time was horizontal, with horizontal bars representing Big Bang, Inflation, etc., and the missions placed within those bars. The Mars group, he said, had a good graphic that divided things between below the surface of Mars, on the surface, and above the surface. Charles Bennett suggested that perhaps the Mars group was looking for things to do, while this group was looking for things to cut. Nicholas White noted that 'What is Dark Energy?' is a big question; however, where does the answer to that question lead? Can questions be phrased so they lead to other questions? Steve Kahn said that if the goal was to understand structure, then understanding the origin of the universe was key. Nicholas White said he thought the questions were too big, too vague and too general.

Sterl Phinney commented that what he liked about Steve Kahn's presentation was that there really were two classes of inquiry: one, about inflation and, related to it, the question of whether the Relativity Theory provides the correct equations; the other was about how those early pieces got combined to make all those things we know nearby and love, including ourselves. Michael Shull said the second question was the interface of physics and astronomy; the first question was physics. Phinney commented that physics and astronomy are not independent. Robert Stern noted that the charts encompassed the highest priorities, but many questions remained unanswered; Explorer Class and other smaller missions might be useful as decision points for these larger missions. Nicholas White commented that the group had its big question, but also needed its decision point questions. Phinney said connections should also be made to ground-based work; theoretically, Dark Energy could be discovered in the lab.

Gary Melnick said that the answer to 'what is dark energy?' was very powerful scientifically, its 'sales' value aside. He noted that the Universe division was going far beyond what could be done with ground based accelerators; by restricting the number of theories of inflation, astronomy could be restraining the number of possibilities for combining quantum mechanics and gravity. This, he said, was a huge step toward a 'theory of everything;' the physics is compelling. Comment: Concern about plans being made too far out: if you know what you want do so in 2030, why aren't you doing it now? Why are you doing other things first? The

response, Charles Bennett said, was that while we know what we want in 2030, we can't get there in a single step. Nicholas White said the learning curve justified the need for probes, and not just big observatories. The group needed to figure out how to cluster its mission suite: why this? What leads to what?

Nicholas White noted that writing assignments would be made by the end of the day, because they would be needed for the April 15 submission. Some discussion on how committee members could confer within FACA constraints. Trish Pengra said the central intent of FACA regulations was to keep the deliberations public; it was permissible for individuals collaborating on a writing assignment to confer. Kathy Flanagan suggested that the group initiate the paperwork for full telecom, in the event that one was deemed necessary.

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GROUP DISCUSSION:
Led by Nicholas White

Nicholas White asked that Sterl Phinney's first chart be re-posted. The chart presented the three basic questions: What powered the Big Bang? What happens to space, time, matter at the edge of a black hole? What is the mysterious Dark Energy pulling the Universe apart? White asked if the group was comfortable with the fourth question: 'How did the infant universe grow into the galaxies, stars and elements?'

Considerable discussion ensued on the wording of question 4. Some thought the phrasing too sterile, and should be altered for better public understanding. Comment: Urge including the word 'we.' Roy Gould said there was a wonderful story for the public in the idea that if you change things even a bit we would have never happened. Robert Stern suggested that if the group was addressing upper levels of NASA and the Senate, more explanation would be needed. Kathryn Flanagan and Sterl Phinney suggested the comments on 'life' not be placed in the top-level questions. Discussion continued; a new wording emerged: 'How did the infant universe grow into galaxies and elements, setting the stage for life?'

Discussion shifted to the Vision missions. Nicholas White asked if the group wished to affirm the inclusion of Big Bang Observer [BBO] and Black Hole Finder [BHF]. Sterl Phinney commented that these missions served as useful endpoints for Beyond Einstein. Steve Kahn expressed concern that Generation-X was a bigger project than Con-X, and Con-X had not yet been done. Michael Shull said he was worried that the mission schedule was too deep in a number of areas. Comment: Suggest that Con-X might provide the answers to what's next; he added that it was difficult to think like a scientist while mapping a PERT chart. Sterl Phinney suggested that the choice on the best way to find the first black holes might rest on the results of BHF and others. Steve Kahn said he regarded LUV/O as a good fit. Nicholas White asked what the decision point was for SAFIR: JWST was the answer given. He next asked about ACT; one possibility was to define it as an additional Einstein probe: what in the current mission suite would trigger a yes/no answer to ACT? Sterl Phinney said that if LISA and JWT disagree on their distance scales, ACT would be needed to resolve the conflict. The consensus, White said, was to retain ACT as there were decision points that might point to its use. Kahn commented that JWST, Chandra, Con-X would develop information about the patterns in the universe; can we explain them? ACT fits with that. White then asked what questions would trigger Stellar Imager. Michael Shull suggested it might best be done in concert with SRM-4 and SRM-10; he thought Stellar Imager was peripheral to multiple roadmaps. White commented that if the current mission suite does not pose a question leading to Stellar Imager, then it doesn't really belong in the roadmap. Next, the committee discussed SPECS. It was suggested that SAFIR might provide a decision point; one can wait to get first results from JWST to decide if there are driving questions that would require the higher resolution SPECS would provide. The question was raised whether SRM-4 had responded to the Vision mission presentations; Kathryn Flanagan responded that SRM-4 had not sought the presentations. Sterl Phinney suggested the group should have the

courage to eliminate several missions. Steve Kahn asked if SPECS should be relocated into SRM-4.

[Lunch break]

Discussion continued after lunch. Ghassem Asrar, NASA Deputy Associate Administrator for Science, spoke to the committee. The committee needed to tell a story, he said, that was coherent and persuasive. He noted the group's struggling with its subordinate set of questions, and that it had moved onto defining how the mission suite was created: what is the common theme from Big Bang to Life. As it had tried to define a question that related life to the physical universe, the group had concluded that it did not do biology. His suggestion was to take the theme of Big Bang to Life. The second point: several times the suggestion was made to transfer something to SRM-4, on the idea that it was not what Universe did. Asrar urged a different approach: eventually, the themes would be drawn together: how does the study of the universe bring us to understand our place within it? He urged the group to look for ways of joining with other roadmap groups.

Michael Salamon commented that if the theme was Big Bang to Life, then large parts of the universe can be laid out: inflation; structure, galaxies, etc. A mission or capability would be directed at each question, e.g. 'How did the galaxies form?' A series of questions, with an answer directed to each. This would connect intellectually, without creating the wiring diagram that some had expressed concern over. Trish Pengra commented that the story the committee was putting together was not a one-dimensional program plan; it included the ability to go back and forth. Michael Shull urged the group to bear these comments in mind, adding that one area of connection with planetary research was that the frequency of planets tied very closely to the creation of metals. Steve Kahn commented that this would permit an ordering to the questions, making it more difficult for someone to say 'why a given project now' as opposed to five years from now. Comment: The fundamental reason for doing astronomy was because "it's killing you to find out."

Ghassem Asrar commented that the theme of life was the prevailing theme in the NASA vision; it has been accepted and endorsed. Flexibility in the architecture was important, he said: if there was no real flexibility scientific discovery, the architecture became a monolithic engineering structure. Robert Stern asked if there was an explicit process by which this roadmap group could discuss interconnected issues with other roadmaps. Asrar said there was; one possibility was a joint session with SRM-4. Michael Salamon said that, for planning, the group needed budget information it did not yet have; it needed to know how the SEU money would be divided between SRM-4 & SRM-8. He expected a program budget in the near future. Anne Kinney [absent] had advised Salamon to determine the science goals; match the missions, then see whether we are within budget.

Ghassem Asrar commented that, at the risk of second-guessing Anne Kinney, he would share the strategic discussion within the directorate: the key point was not to talk about specific missions and budgets; rather, that once the strategic RM are together and Universe division has a plan of action, you will want to know what are ground rules for achieving those objectives. We want to establish open-edited lines and share this philosophy in the community. The question becomes: do we need to have all of these lines in our tool kit for executing the program? What is the right combination of these lines to define the ground rules for planning and the ground rules for executing the program? This moves you to an extent beyond planning to execution; you can define a plan that is extremely exciting but too expensive. On the other hand, if you focus too much on nuts and bolts you can take the excitement out of it. He suggested, further, that Universe look to how it could share costs with other SRMs.

Michael Shull asked by what measure the group should over-select: double? Triple? Ghassem Asrar noted the tendency to underestimate the cost and time, and quite often get ourselves and others in trouble. NASA, he added, is attempting to fix that problem; over-selection is good to a point. Robert Stern said the problem Asrar was citing was mostly of the past three to five years. Asrar said that NASA tended to gravitate toward risk, until something doesn't work, then swing toward caution; a balance has not been found. Robert Stern said that at present. NASA was swinging to a high process level; it's getting very cumbersome. He said that NASA

was imposing on private contractors doing small undertakings the methods by which it does very large missions; this added cost and time. Asrar called attention to the increasing role played by foreign collaborations; Michael Salamon noted that the roadmap was to address possible collaborations, foreign included. Nicholas White suggested that further discussion on probes be differed to the next meeting, which he would attempt to schedule with SRM-4.

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DISCUSSION OF APRIL 15 DRAFT STRATEGIC ROADMAP:
Led by Nicholas White

Nicholas White turned discussion to the group's April 15 submission. Michael Salamon distributed 'Preparing the Interim Report for Strategic Roadmap #8,' which gives the submission's outline as: roadmap achievements, roadmap requirements, roadmap summary and other information. He noted that at present there were two sets of primary questions, from Steve Kahn and Sterl Phinney. In answer to a question, Salamon said that 'roadmap achievements' meant expected outcomes and mapped to missions. He called attention to the 'roadmap goal structure' on page 3 of his presentation, saying the question was how to combine the questions presented by Phinney and Stern. Once those questions were established, the next task is to define the achievements in each decade.

Nicholas White asked if the group accepted the five questions. Kathryn Flanagan suggested that question 5 was weak. Michael Shull noted that 'a lot of the astronomy' goes in question 4; out of collegiality, he suggested adding the word 'stars' to 'galaxies and elements.' Kathryn Flanagan suggested that question 4's final word be 'life.' After consensus, question 5 was eliminated; Comment: This eliminates 'the sexy phrase dark matter.' Others commented that it need not be a first order statement to be included.

Completed questions were:

Question 1: What powered the Big Bang?
Question 2: What happens to space, time, matter at the edge of black hole?
Question 3: What is the mysterious dark energy pulling the Universe apart?
Question 4: How did the infant universe grow in to galaxies, stars and elements, setting the stage for life?

Next, missions were mapped against a grid that used the questions as the vertical axis and time as the horizontal access. Nicholas White suggested placing Gen-X, Black Hole Imager, and Black Hole Observer on the far right of the time access. Considerable discussion ensued as to where particular missions should be placed on this grid. White suggested adding an 'overarching question' at the top of the graph: 'How do we get from the Big Bang to Life?'

Nicholas White said he would be making writing assignments; Kathryn Flanagan suggested they be made now, so persons selected could take appropriate notes. The first set of assignments was:

Big Bang [question 1]: Craig Hogan; Charles Bennett
Black Holes [question 2]: Sterl Phinney; Nicholas White
Dark Energy [question 3]: Steve Kahn; Michael Turner
Setting the stage [question 4]: Bob Stern; Michael Shull; Jakob van Zyl; Rene Ong

Sterl Phinney suggested that the chart be layered, horizontally, into bands identified as Big Bang, Inflation, etc. Further, Phinney expressed concern that the product of this work not be cast in stone; White commented that its immediate purpose was the April 15 document.

Nicholas White moved the group on to the second level questions and decision points. Considerable discussion ensued; as a consensus was reached on individual missions, the information was entered onto a screen within the committee's view. Nicholas White commented that he thought it important that those doing the writing know what the major branching points were. Comment: Urge the group not to put every mission in the chart; if it did so, that might

suggest no additional missions were needed. This was not an exercise in inclusiveness, he said, but in strategic planning. Craig Hogan said the writing assignment would flesh out the questions and show the connections to the science questions. Steve Kahn noted that, in order to frame things as achievements, the presentation must show what each mission can achieve. Nicholas White noted that agreement was needed on what fell in the first, second or third decade. Kathryn Flanagan commented that the year dates were for accomplishment, not for launch.

The following launch dates were established:

2005-2015

GLAST	2007
Probe-1	2008
JWST	2011
LISA	2013

2015-2025

Cox-X	2017
Probe-2	2018
SAFIR	2020
Probe-3	2022
ACT	

2025+

Big Bang Observer
Black Hole Imager
Gen-X
SPECS
LUV/O
Probe-4
Probe-5

Ron Polidan noted that the sensors capabilities group was discussing missions not listed here. Nicholas White made additional writing assignments, as follows:

Roadmap requirements: Ron Polidan, assisted by Craig Hogan
Roadmap summary: Co-chairs
Other information, including the international aspect: Nicholas White
Information on cost of roadmap elements: Louis Barbier

Robert Stern asked how coordination could be achieved with SRM-4. Comment: Suggest additional coordination with SRM-10. The question was posed which two probes should launch first. Sterl Phinney urged Dark Energy [JDEM] and Black Hole Finder – as the Einstein concept had wide acceptance and readiness was high. Craig Hogan said he favored JDEM; it offered a very broad scope. Michael Shull suggested launching first whichever of the three probe projects presented the best proposal. Kathryn Flanagan said the probes were too different to allow that. Ron Polidan added his endorsement of JDEM. Nicholas White asked what the mission cost cap should be. The cost had to be total cost, Michael Salamon suggested, and not dependent on a collaborator who might withdraw; he suggested the figure of $600 million. Charles Bennett expressed concern that it had not yet been determine what was possible at what price. With Bennett's dissent, the committee approved to suggestion.

SCHEDULING:

The committee discussed two teleconferences, a technical one [not requiring federal meeting notice filing] for March 28; a full one, requiring such notice, for April 8. Michael Salamon said he would make the arrangements. The deadline for written submissions was discussed, and set for

March 28. Regarding the group's next meeting, Nicholas White said he would attempt to schedule a joint session with SRM-4.

The meeting adjourned at 3:35 p.m., Wednesday, March 16.

Agenda
NASA Strategic Roadmap Committee 8 Second Meeting
Greenbelt Marriott Hotel, Greenbelt, MD
March 15-16, 2005

Tuesday, March 15:

8:30am—8:45am	Discussion of the Agenda	Nick White, GSFC
8:45am—9:20am	Planning for Draft Roadmap Products, Upcoming NRC Review, Preparation of Final Report	Michael Salamon, HQ
9:20am—10:20am	**Vision Mission Presentations:**	Anne Kinney, HQ
	(1) Big Bang Observer	Sterl Phinney, Caltech
	(2) Black Hole Imager (MAXIM)*	Keith Gendreau, GSFC
	(3) Generation-X	Dan Schwartz, SAO
	(4) Large UV/Optical Telescope	Jim Green, U. Colo.
10:20am—10:30am	Coffee Break	
10:30am—11:30am	**Vision Mission Presentations, continued:**	Anne Kinney, HQ
	(5) SAFIR	Dan Lester, U. Texas
	(6) Advanced Compton Telescope	Steve Boggs, UC/Berk.
	(7) Stellar Imager	Ken Carpenter, GSFC
	(8) Far-IR & Sub-mm Interferometer	Martin Harwit, Cornell
11:30am—12:30pm	Discussion of Vision Missions for inclusion as far-term missions in SR	Nick White, GSFC
12:30pm—1:30pm	Working Lunch/Input from Community	
1:30pm—3:10pm	**Einstein Probes:**	Anne Kinney, HQ
1:30pm—2:20pm	CMB Task Force Report	Rai Weiss, MIT
2:20pm—2:50pm	Report from JDEM SDT	Charles Bennett, JHU
2:50pm—3:10pm	Black Hole Finder Probe	Neil Gehrels, GSFC
3:10pm—3:25pm	Coffee Break	
3:25pm—5:30pm	**Origins Probes:**	Nick White, GSFC
	(1) Discussion of Origin Probes Presentations	Eric Smith, HQ
	(2) An Origins Probe Line? Universe Probes Line?	
	(3) What to do about Opt/UV in the Post-Hubble Era?	
5:30pm—6:00pm	Planning for Tomorrow	Nick White, GSFC

Wednesday, March 16:

8:30am—9:00am	Education/Public Outreach	Roy Gould, CFA
9:00am—10:00am	APIO White Papers/Roundtable Discussion	Kathy Flanagan, MIT
10:00am—10:30am	Structures: Setting the Stage for Life	Nick White, GSFC
10:30am—10:45am	Coffee Break	
10:45am—11:15am	Structures: Setting the Stage for Life (cont.)	Nick White, GSFC
11:15am—12:00pm	Inclusion and Prioritization (initial)	Anne Kinney, HQ
12:00pm—1:00pm	Working Lunch	
1:00pm—2:00pm	Inclusion and Prioritization (continued)	Anne Kinney, HQ
2:00pm—4:30pm	Items for April 15 Draft Strategic Roadmap Technology Issues Preparation of Charts	Nick White, GSFC
4:30pm—5:00pm	Plans for Next Meeting	Kathy Flanagan, MIT

Appendix 2: Committee members

Dr. Kathryn Flanagan, co-chair, Massachusetts Institute of Technology
Dr. Anne Kinney, co-chair, NASA Headquarters
Dr. Nick White, co-chair, NASA Goddard Space Flight Center

Dr. Chuck Bennett, NASA Goddard Space Flight Center
Dr. Craig Hogan, University of Washington
Dr. Steve Kahn, Stanford University
Dr. Rene Ong, University of California, Los Angeles
Dr. Sterl Phinney, California Institute of Technology
Dr. Ron Polidan, Northrop Grumman Space Technology
Dr. Michael Shull, University of Colorado
Dr. Bob Stern, Lockheed Martin Solar and Astrophysics Laboratory
Dr. Michael Turner, National Science Federation
Dr. Jakob van Zyl, Jet Propulsion Laboratory

Liaison and ex officio members:
Dr. Louis Barbier, NAS Goddard Space Flight Center, ex-officio
Dr. Roy Gould, Education Roadmap Committee Liaison
Dr. Steve Maran, American Astronomical Society, ex-officio

Staff:
Dr. Rich Capps, APIO coordinator
Dr. Michael Salamon, directorate coordinator
Dr. Gary Blackwood, Jet Propulsion Laboratory, systems engineer

Appendix 3: Persons present

The following individuals were signed in on Tuesday, March 15:

Louis Barbier, ex-officio
Chuck Bennett, Johns Hopkins University
Mark Bernstein, Infonetic
Steve Boggs, UC/Berkeley
Dwayne Day, SSB
J. J. Dolan, NASA/Goddard
Derrick Eckhardt, Boeing
Steve Evangelista, SRI International
Giovanni Fazio, CFA
Kathryn Flanagan, MIT/member
Neil Gehrels, NASA Goddard
Keith Gendreau, NASA Goddard
Roy Gould, SAO
James Green, University of Colorado
Michael Hampton, UC/Berkeley
F. Rick Harnden, NASA HQ
Martin Harwit, Cornell University
Richard Conn Henry, Johns Hopkins University
Paul Hertz, NASA HQ
W. Vernon Jones, NASA HQ
Steve Kahn, member
Margarita Karouska, SAO
Anne Kinney, NASA
Jim Kurfess, NRL
David Leisawitz, NASA Goddard
Daniel Lester, University of Texas
Michael Levi, LBNL
Steve Maran, AAS
Gary Melnick, CFA
Trish Pengra, NASA
Ron Polidan, NASA Goddard
Bill Purcell, Ball Aerospace
Sterl Phinney, Cal Tech
Ron Polidan, member
Steve Reinhart, NASA Goddard
Jeff Roth, Johns Hopkins University
Michael Salamon, member
Dan Schwartz, SAO
Michael Shull, University of Colorado
Eric Smith, NASA HQ
Robert Stern, member
Kathleen Turner, US Department of Energy
Jakob van Zyl, member
Nick White, NASA Goddard

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The following individuals were signed in on Wednesday, March 16:

Ghassem Asrar, NASA HQ
Zaran Arzoumanian, NASA Goddard
Robert Banes, NASA
Louis Barbier, ex-officio
Chuck Bennett, Johns Hopkins University
Mark Bernstein, Infonetic
Richard Capps, NASA APIO/Jet Propulsion Laboratory
Derrick Eckhardt, Boeing
Giovanni Fazio, CFA
Kathryn Flanagan, MIT
Roy Gould, SAO
Paul Hertz, NASA HQ
Craig Hogan, University of Washington
Steve Kahn, member
Jim Kurfess, NRL
Dave Leisawitz, NASA Goddard
Steve Maran, AAS
Gary Melnick, CFA
Trish Pengra, NASA
Bill Purcell, Ball Aerospace
Sterl Phinney, Cal Tech
Ron Polidan, member
Michael Salamon, member
Michael Shull, University of Colorado
Robert Stern, member
Jakob van Zyl, member
Nick White, NASA Goddard
Jennifer Wisenman, NASA HQ

Appendix 4: List of Presentation Materials

Universe Strategic Roadmap session
March 15-16, 2005
Greenbelt, Maryland

John Bally, et al: *Next Large UV-Optical Space Telescope*

Steve Boggs, University of California/Berkeley, et al: *The Advanced Compton Telescope Mission*

K. O. Carpenter, NASA Goddard Space Flight Center, et al: *The Stellar Imager [SI} 'Vision Mission'*

Martin Harwit, Cornell University: *Sub-millimeter Probe of the Evolution of Cosmic Structure [SPECS]*

S. M. Kahn, Stanford University: *Some Ideas on How to 'Structure' the Universe Roadmap*

Dan Lester, University of Texas: *The Single Aperture Far Infrared Telescope [SAFIR}*

Michael Salamon, directorate coordinator; Marc Allen, Advanced Planning and Integration Office: *Preparing the Interim Report for Strategic Roadmap #8, due April 15, 2005.*

Scott Sanford, principal investigator: *The Astrobiology Space Infrared Explorer [ASPIRE] Origins Probe Concept Mission*

Sterl Phinney, California Institute of Technology: *Big Bang Observer*

Sterl Phinney, California Institute of Technology: *Roadmap Structure: How do we get from the Big Bang to Life?*

Dan Schwartz, Smithsonian Astrophysical Observatory: *The Generation-X Vision Mission*

Eric P. Smith, NASA Universe Division: *Origins Probes Concept Studies*

[NOTE: Presentation and other materials distributed at the meeting are on file at NASA Headquarters Science Mission Directorate, Washington DC 20546.]